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(54) **NOISE REDUCTION DEVICE AND BUS BAR MODULE**

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H01F 37/00 (2006.01)
H01F 41/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H01F 37/00*** (2013.01); ***H01F 17/06*** (2013.01); ***H01F 41/00*** (2013.01); *H01F 2017/065* (2013.01); *Y10T 29/4902* (2015.01)

(58) **Field of Classification Search**
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USPC 336/174–177, 212; 333/12, 185; 324/127; 174/36; 429/99; 29/602.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,710,006 A * 1/1973 Davis 174/101.5
4,970,476 A * 11/1990 Kitagawa 333/12
6,462,268 B1 * 10/2002 Hazy et al. 174/36
(Continued)

FOREIGN PATENT DOCUMENTS

CN 101395737 A 3/2009
GB 2 361 111 A 10/2001
(Continued)

OTHER PUBLICATIONS

Partial Translation of Office Action issued in Japanese Application No. 2011-051803 issued Mar. 3, 2014.

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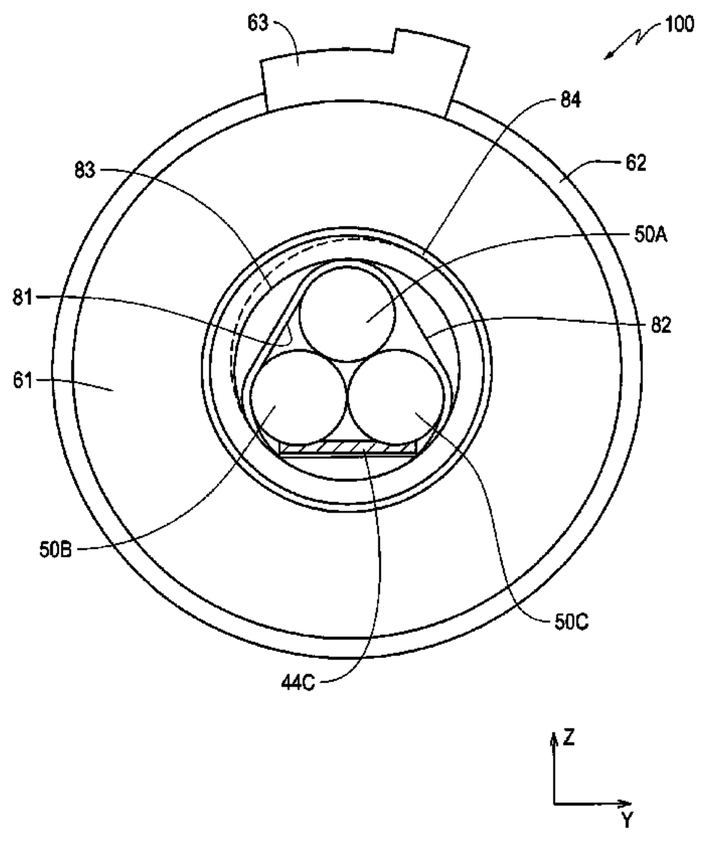
(57) **ABSTRACT**

A noise reduction device includes a magnetic core and an elastically deformable elastic sheet. The magnetic core surrounds an outer periphery of an electric cable, and reduces noise emitted from the electric cable. The elastic sheet is wrapped around the electric cable so as to surround the electric cable, and is sandwiched between an inner peripheral surface of the magnetic core and an outer peripheral surface of the electric cable and elastically deformed.

10 Claims, 5 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0285708	A1	12/2005	Berens et al.	
2009/0274952	A1 *	11/2009	Wood et al.	429/99
2010/0021802	A1	1/2010	Yang et al.	

FOREIGN PATENT DOCUMENTS

JP	U-2-45697	3/1990
JP	A-05-043843	2/1993
JP	A-7-170631	7/1995
JP	A-11-209706	8/1999
JP	A-2001-167933	6/2001
JP	A-2004-193316	7/2004
JP	A-2005-011961	1/2005
JP	A-2007-266082	10/2007
JP	A-2008-098458	4/2008
JP	A-2009-205865	9/2009

* cited by examiner

FIG. 1

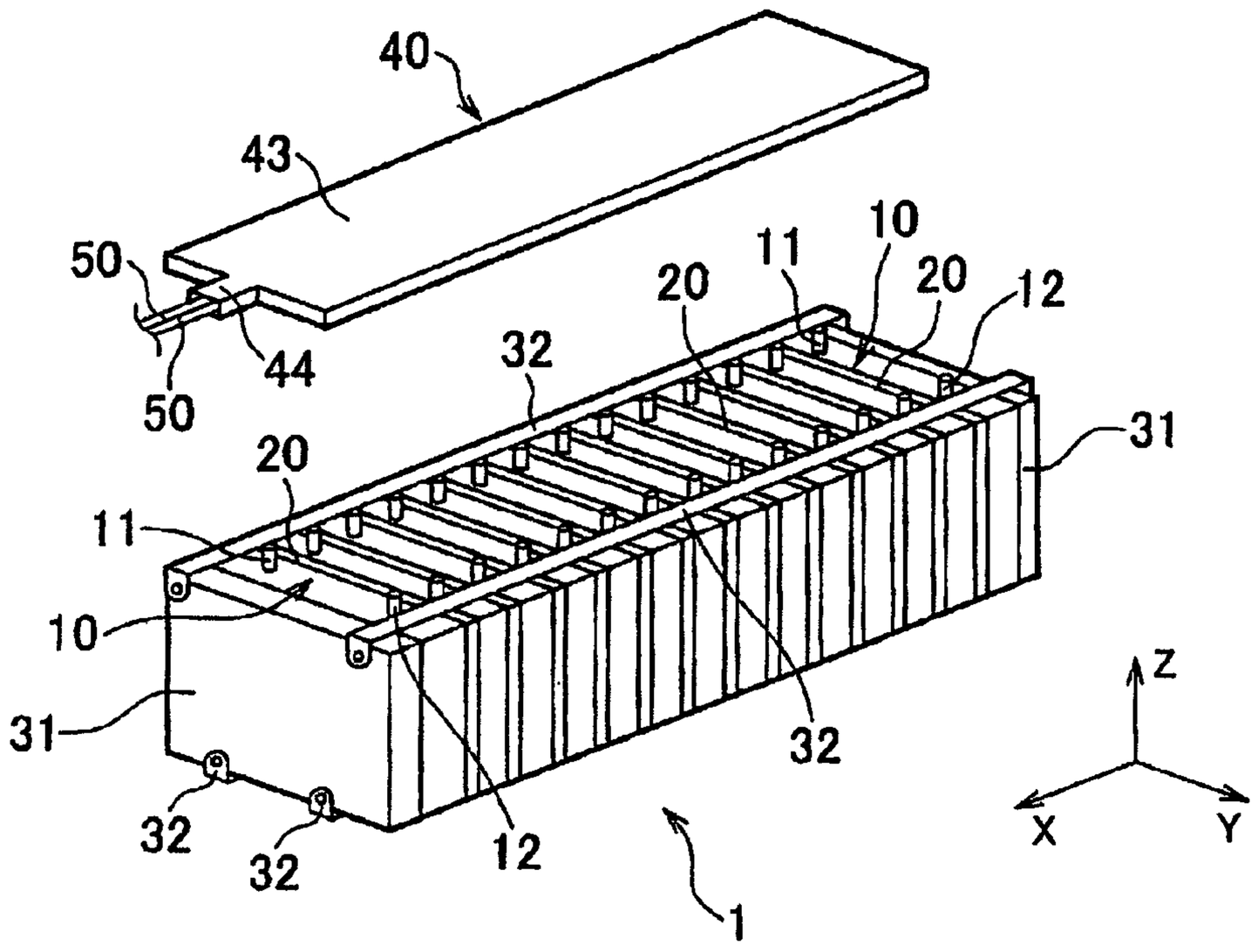

40
43
50
44
50
20
11
10
20
12
32
31
20
11
10
31
32
32
32
12
1
Z
X
Y

FIG. 2

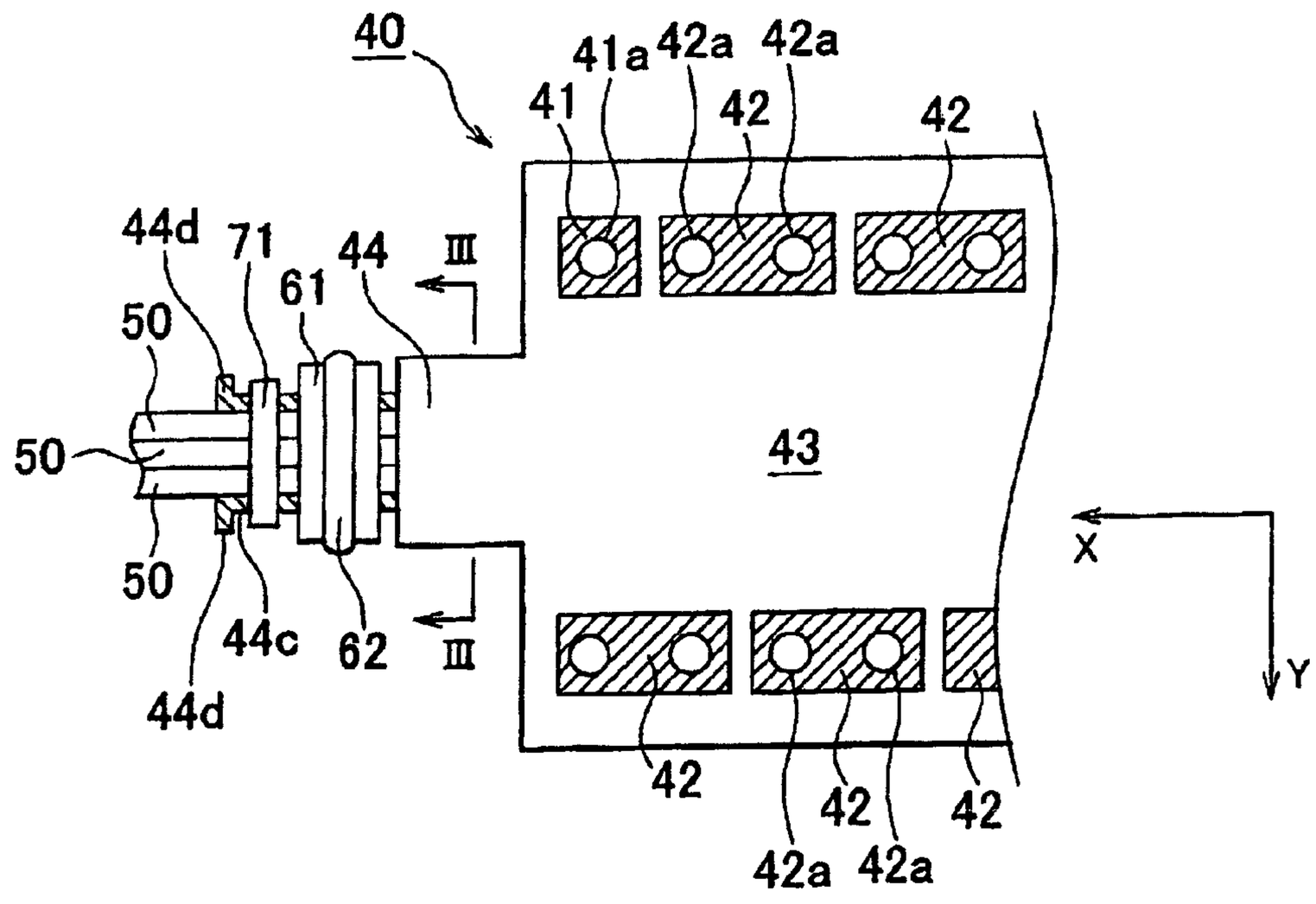

40
41a
42a
42a
41
42
42
44d
71
61
44
III
50
50
50
44c
62
III
44d
43
X
Y
42
42
42
42a
42a

FIG. 3

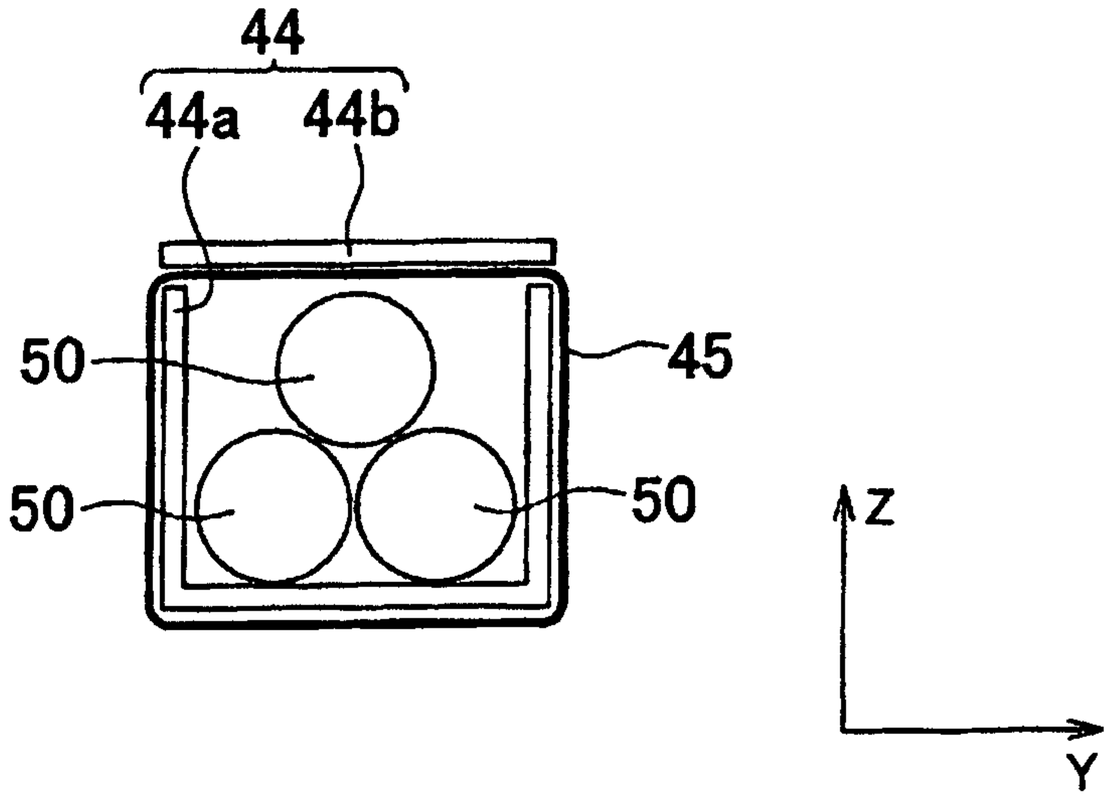


FIG. 4

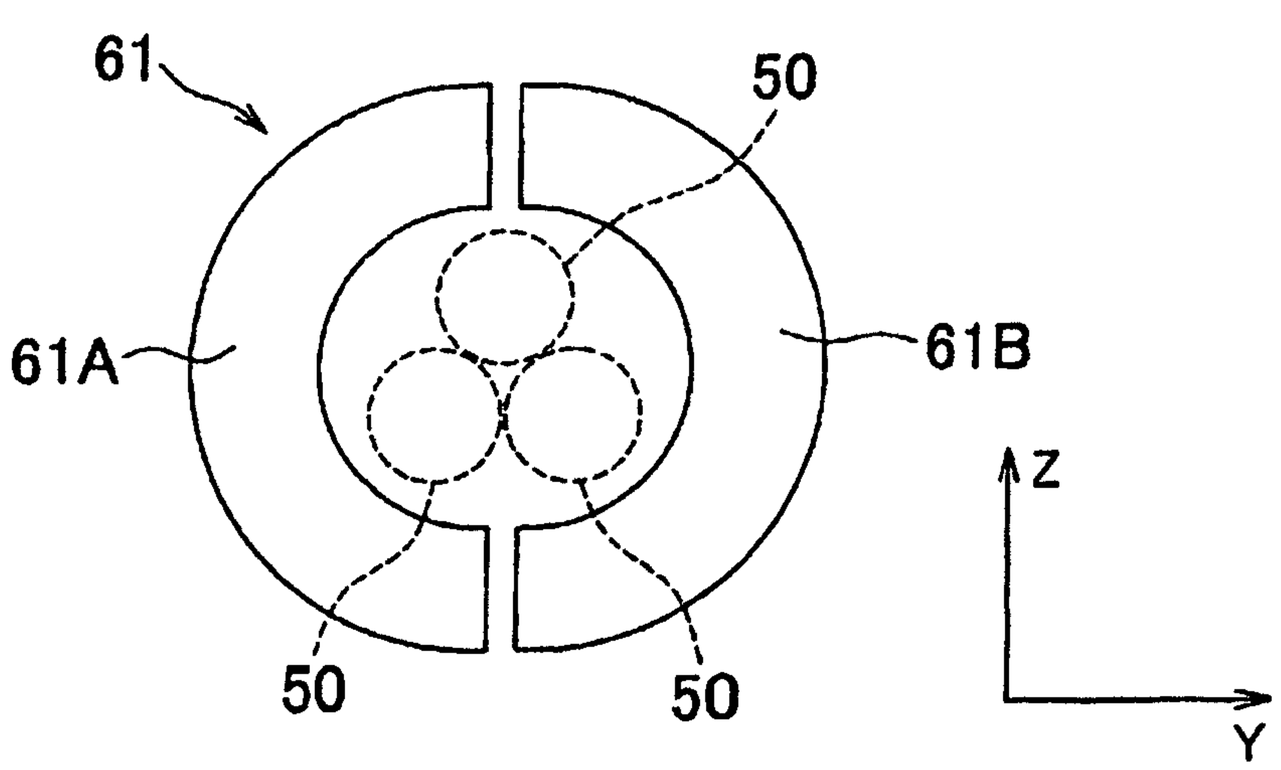


FIG. 5

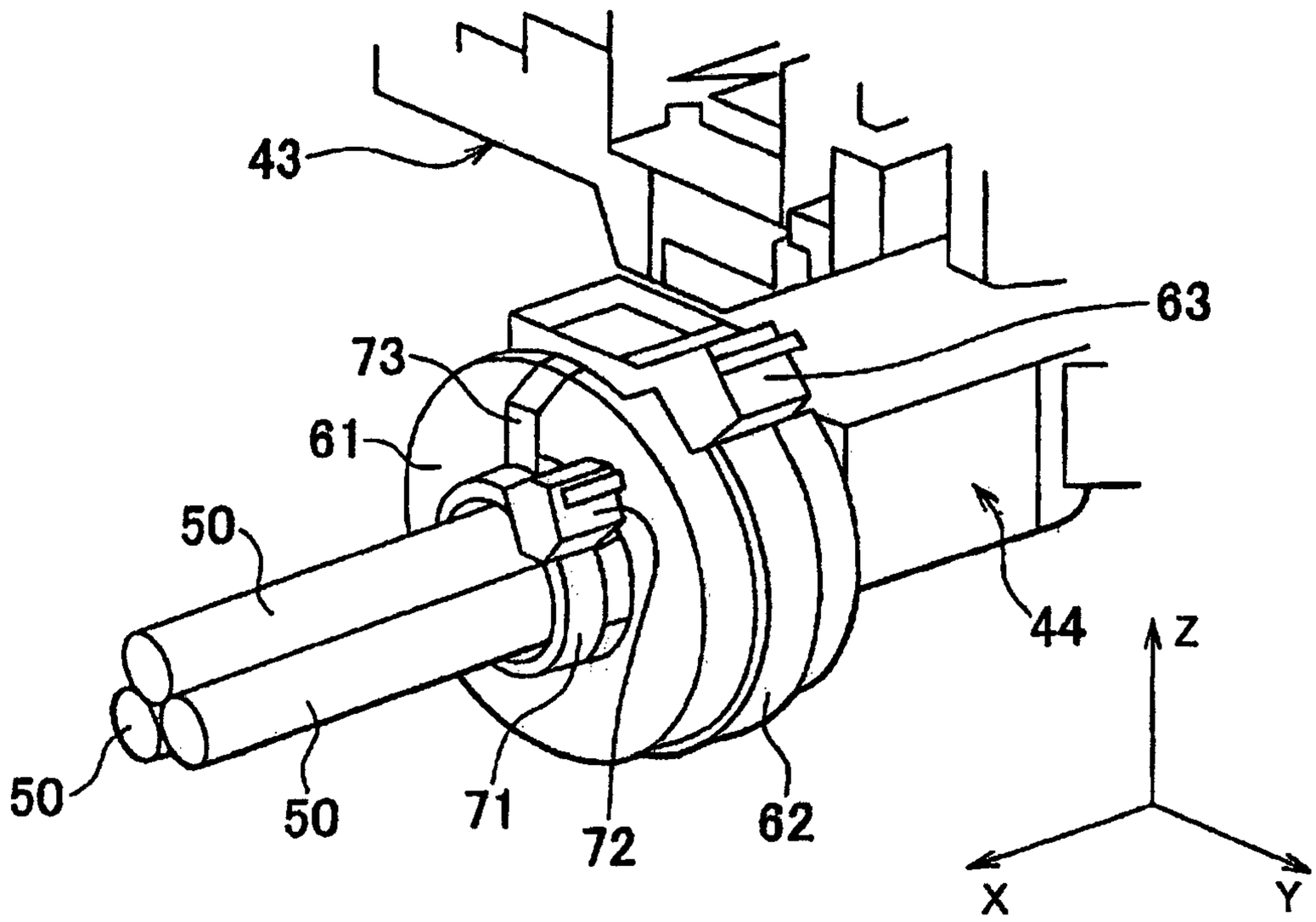

43
63
73
61
50
50
50
71
72
62
44
Z
X
Y

FIG. 6

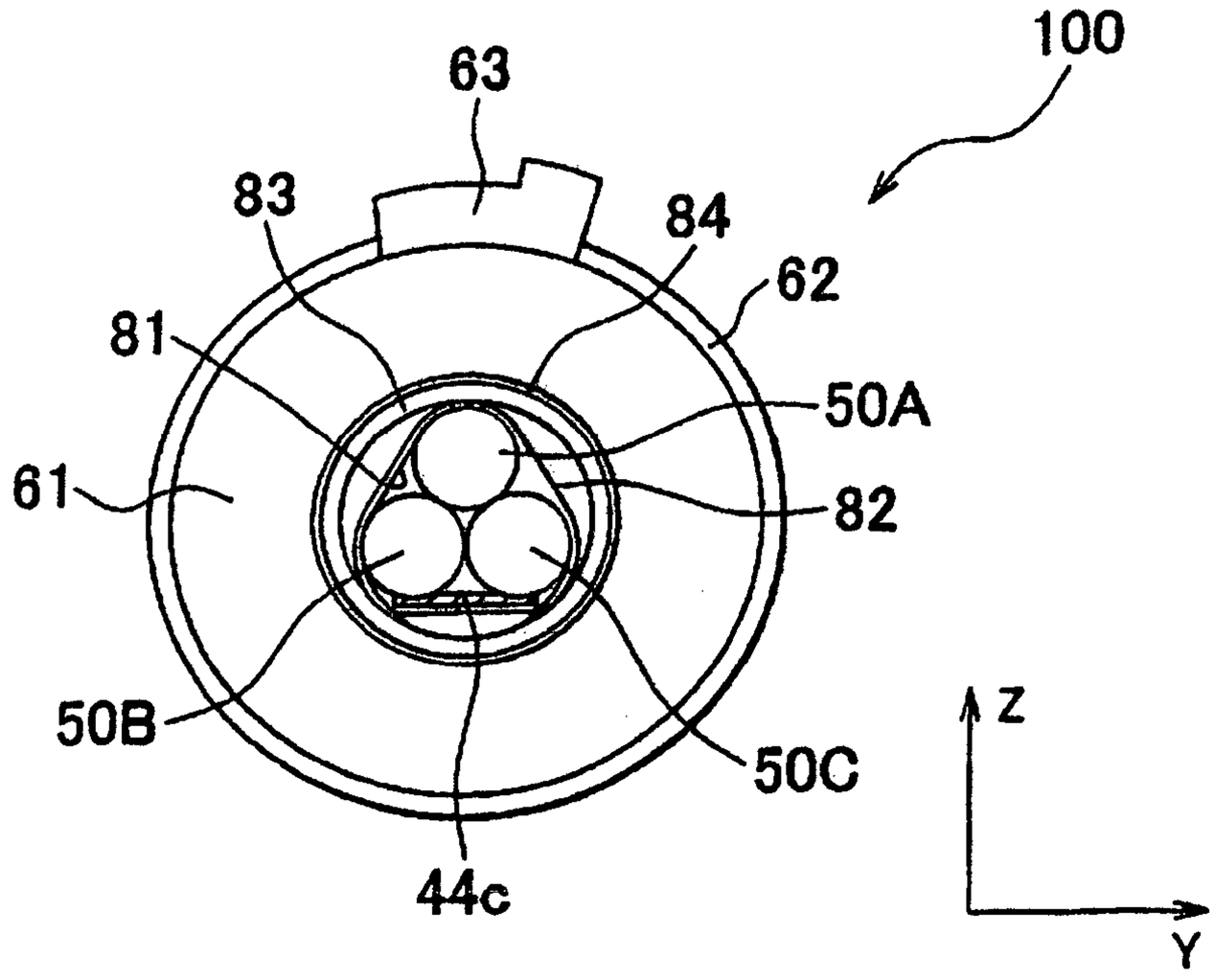

63
100
83
84
62
81
50A
61
82
50B
50C
44c
Z
Y

FIG. 7

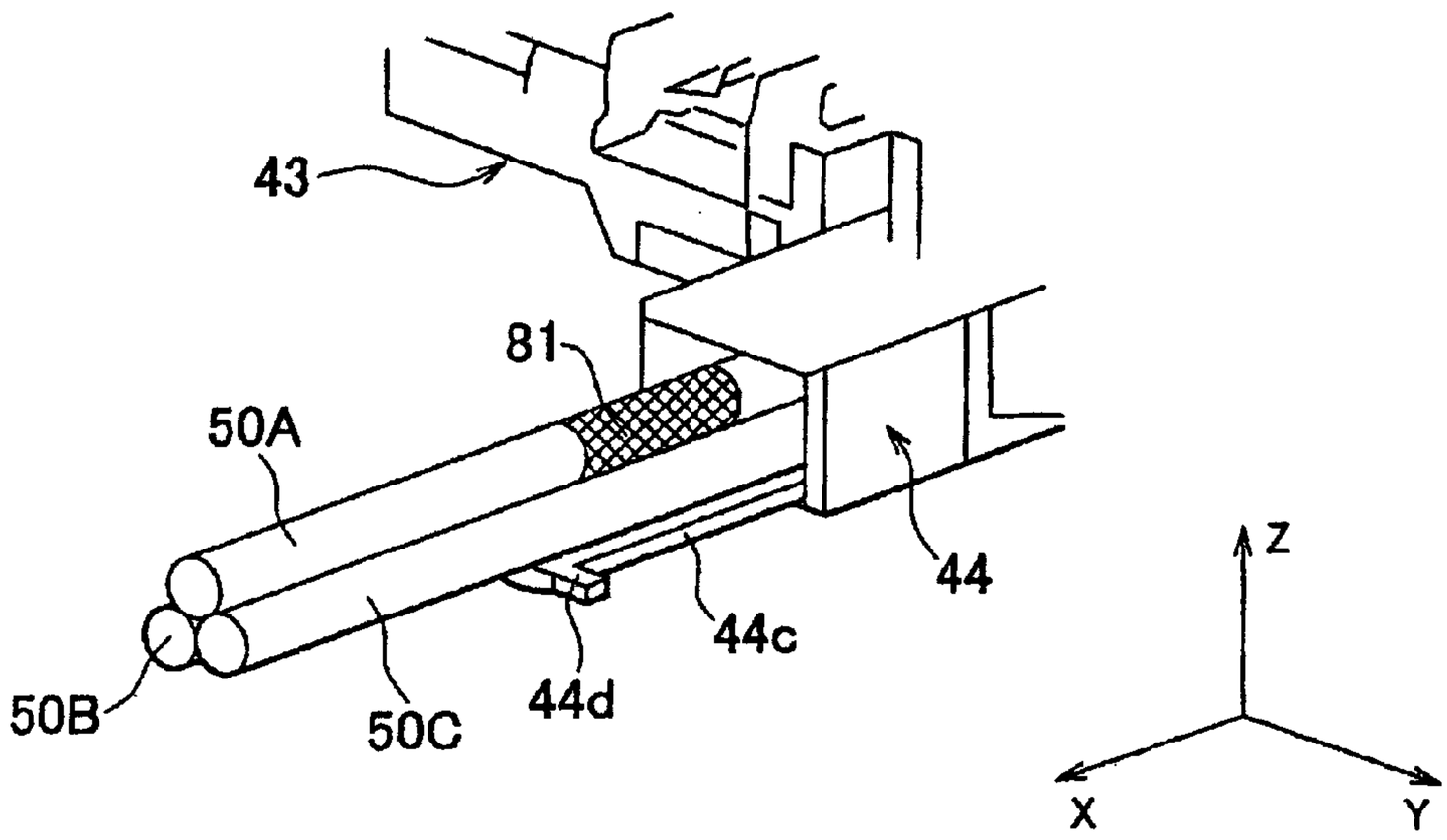
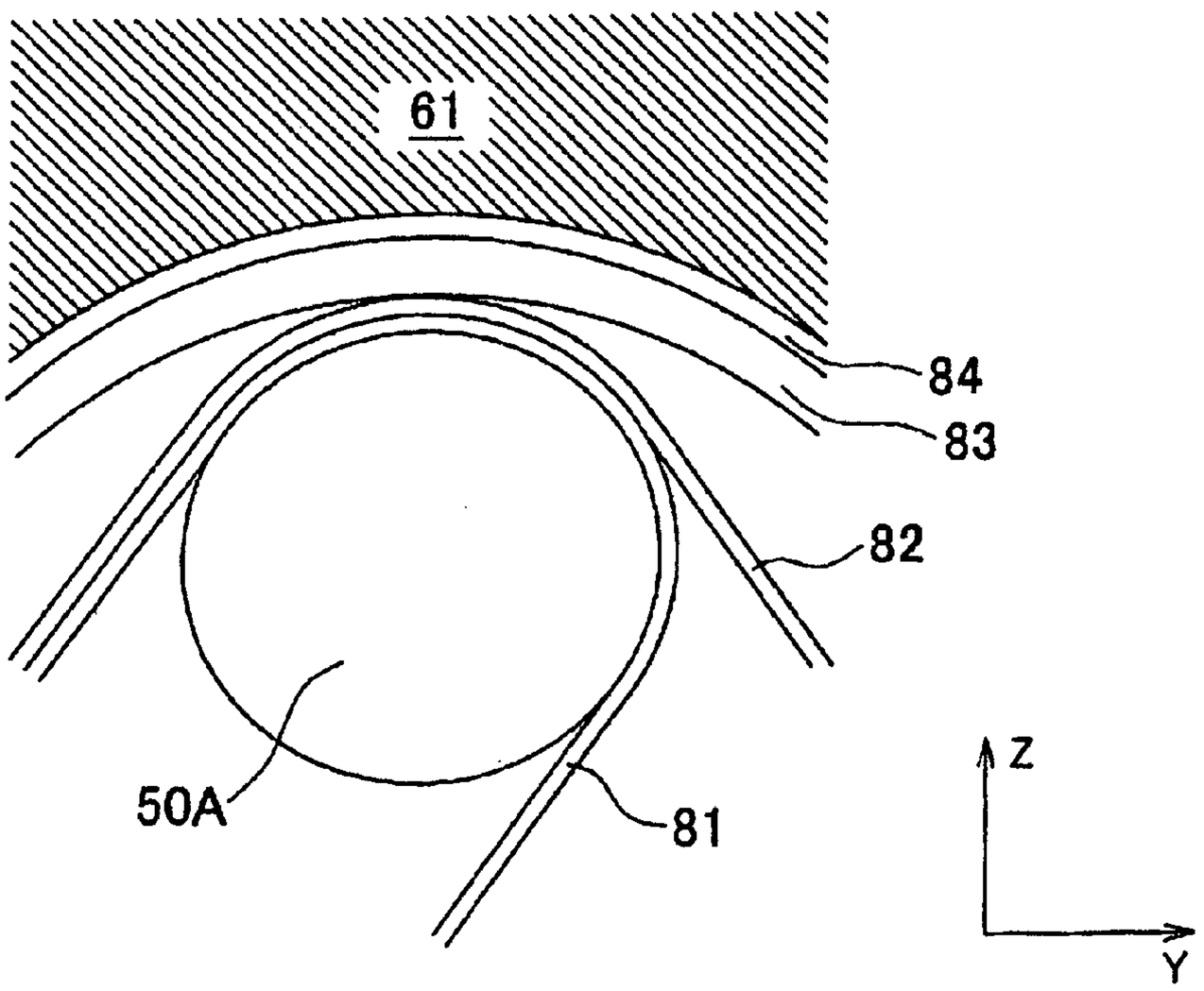


FIG. 8



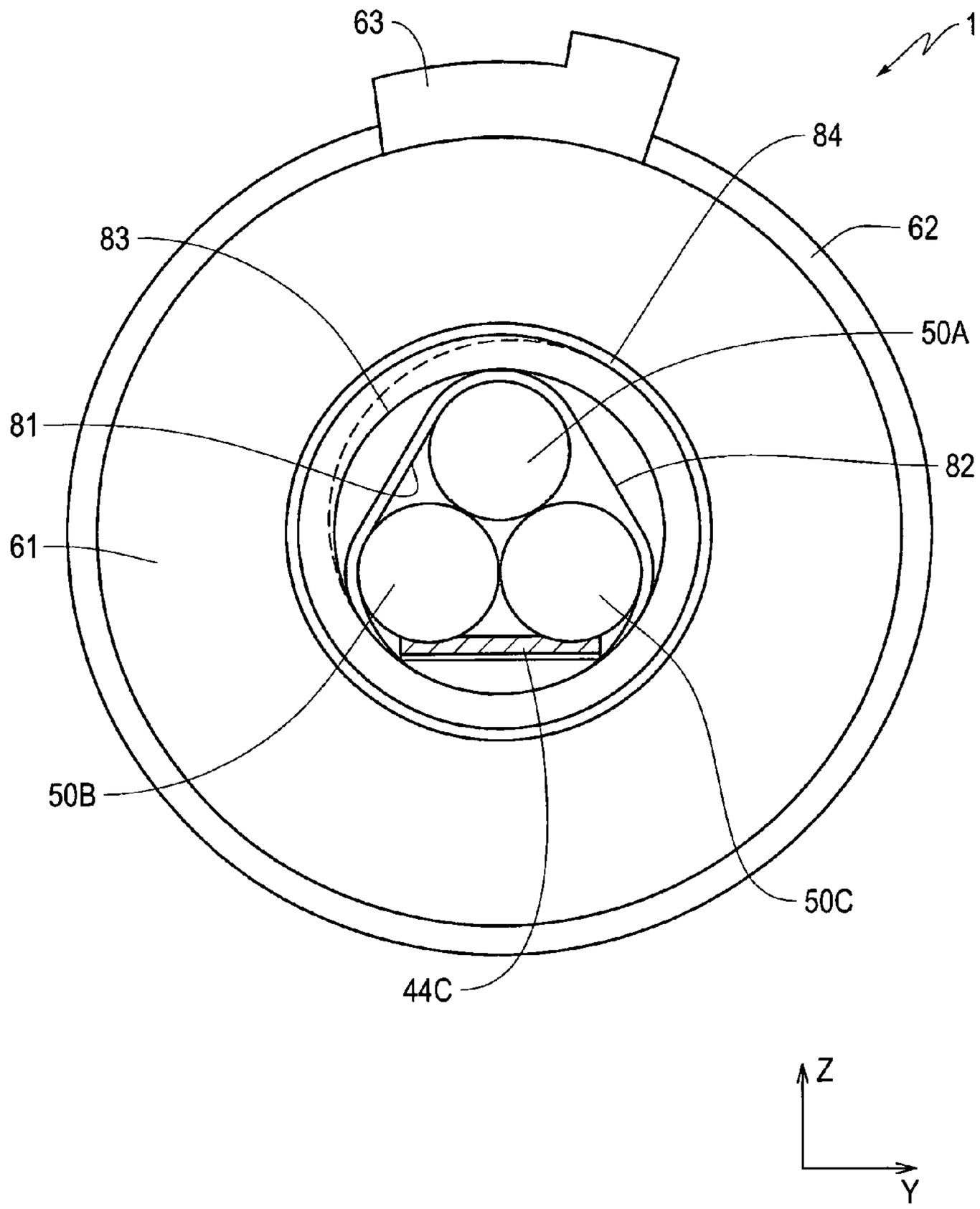


FIG. 9

NOISE REDUCTION DEVICE AND BUS BAR MODULE

BACKGROUND OF THE INVENTION

1 . Field of the Invention

The invention relates to a noise reduction device that reduces noise emitted from an electric cable, and a bus bar module provided with this noise reduction device.

2 . Description of Related Art

Technology exists that reduces noise emitted from an electric cable, by attaching a magnetic core to the electric cable. Here, in Japanese Patent Application Publication No. 2005-011961 (JP 2005-011961 A), an elastic member made of gel-like resin is filled onto a surface of a magnetic core that faces an electric wire, and the magnetic core is fixed to the electric wire using the deformation force of the elastic member.

Also, in Japanese Patent Application Publication No. 2004-193316 (JP 2004-193316 A), it is possible to fix a magnetic core to an electric cable even if the diameter of the electric cable is different, by providing a member that holds the electric cable to a case of the magnetic core.

In the case of JP 2004-193316 A, the structure of the case ends up becoming complex by the provision of the member that holds the cable. In the case of JP 2005-011961 A, the shape of the elastic member must be changed according to the diameter of the electric wire that is held by the elastic member. That is, it is necessary to prepare as many elastic members in different shapes as the number of electric wires of different diameters.

SUMMARY OF THE INVENTION

A first aspect of the invention is a noise reduction device that includes a magnetic core and an elastic sheet. The magnetic core surrounds an outer periphery of an electric cable and reduces the noise emitted from the electric cable. The elastic sheet is wrapped around the electric cable so as to surround the electric cable, and is sandwiched between an inner peripheral surface of the magnetic core and an outer peripheral surface of the electric cable and elastically deformed.

A wear-resistant sheet may be arranged between the magnetic core and the elastic sheet. Using a wear-resistant sheet makes it possible to prevent the elastic sheet from wearing due to contact between the elastic sheet and the magnetic core.

At least a portion of the elastic sheet may overlap another portion of the elastic sheet when wrapping the elastic sheet around the electric cable. Accordingly, even if the relationship between the size (i.e., the diameter) of the electric cable and the magnetic core changes, the gap between the magnetic core and the electric cable can be filled with the elastic sheet. A foam, for example, may be used as the elastic sheet.

The magnetic core and the elastic sheet may surround a plurality of electric cables. When using a plurality of electric cables, the plurality of electric cables may be bundled together using an adhesive tape. An elastic sheet may be wrapped around the bundled plurality of electric cables. Bundling the plurality of electric cables together makes it easy to wrap the elastic sheet around the electric cables.

Also, using an adhesive tape makes it possible to position the plurality of electric cables in the longitudinal direction of the electric cables. For example, when a connector is provided on a tip end of each electric cable, the connectors can be positioned by positioning the plurality of electric cables. As a result, the connectors can be arranged in a predetermined connecting position, so that the connectors can be connected easily.

A second aspect of the invention relates to a bus bar module that includes a plurality of bus bars, a holder, and an electric cable. The plurality of bus bars are used to electrically connect a plurality of power storage elements together. The holder holds the plurality of bus bars and is made of insulating material, such as resin. One end of the electric cable is fixed to the holder and a portion of the electric cable on the other end side is drawn out of the holder. The noise reduction device according to the first aspect described above may be used in this kind of bus bar module.

In this bus bar module, when a plurality of electric cables are used, a guide portion that guides the plurality of electric cables to an attaching position of the noise reduction device may be provided on the holder. Using the guide portion makes it possible to gather the plurality of electric cables together in one place, so that the noise reduction device can easily be attached to the plurality of electric cables.

A third aspect of the invention relates to a manufacturing method for a noise reduction device that has a magnetic core that surrounds an electric cable. This manufacturing method includes wrapping an elastically deformable elastic sheet around the electric cable so that the elastic sheet surrounds the electric cable; and elastically deforming the elastic sheet by attaching the magnetic core to the electric cable that is surrounded by the elastic sheet.

In wrapping the elastic sheet around the electric cable, a wrapped state of the elastic sheet with respect to the electric cable may be changed according to a diameter of the electric cable and an inside diameter of the magnetic core. The wrapped state of the elastic sheet includes, for example, a state in which the elastic sheet is wrapped around the outer periphery of the electric cable only once, and a state in which the elastic sheet is wrapped around the outer periphery of the electric cable a plurality of times.

According to the invention, the restoring force of the elastically deformed elastic sheet makes it possible to fix the magnetic core to the electric cable and inhibit the magnetic core from slipping with respect to the electric cable. In addition, the elastic sheet is wrapped around the electric cable, and therefore, even when an electric cable having a different diameter is used, the magnetic core can be fixed to the electric cable simply by changing the wrapped state of the elastic sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. **1** is an external view of a cell stack according to an example embodiment of the invention;

FIG. **2** is a plan view of a portion of a bus bar module according to the example embodiment;

FIG. **3** is a sectional view taken along line III-III in FIG. **2**;

FIG. **4** is a diagram of a structure of a magnetic core according to the example embodiment;

FIG. **5** is a diagram of a structure around the magnetic core according to the example embodiment;

FIG. **6** is a diagram of a structure arranged inside the magnetic core according to the example embodiment;

FIG. **7** is a diagram of an arrangement of an electric cable according to the example embodiment; and

FIG. **8** is an enlarged view of a portion of a structure arranged inside the magnetic core according to the example embodiment.

FIG. **9** is an enlarged view of the structure illustrated in FIG. **6**.

DETAILED DESCRIPTION OF EMBODIMENT

Hereinafter, example embodiments of the invention will be described.

A cell stack according to one example embodiment of the invention will now be described. FIG. **1** is an external view of a cell stack according to this example embodiment. In FIG. **1**, the X axis, the Y axis, and the Z axis are all orthogonal to one another. In this example embodiment, the axis corresponding to the vertical direction is the Z axis. The relationships between the X axis, the Y axis, and the Z axis are the same for the other drawings as well.

A cell stack **1** shown in FIG. **1** is housed in a pack case (not shown). The cell stack **1** and the pack case together form a battery pack. The battery pack is able to be mounted in a vehicle, for example. By converting electric energy output from the battery pack to kinetic energy using a motor-generator, the vehicle can be made to run using this kinetic energy. When the vehicle is stopped or decelerated, by converting kinetic energy generated when braking the vehicle into electric energy using a motor-generator, this electric energy can be stored in the battery pack.

The cell stack **1** has a plurality of single cells (power storage elements) **10** lined up in the X direction. Secondary batteries such as nickel-metal hydride batteries or lithium ion batteries may be used as the single cells **10**. Also, electric double layer capacitors (capacitors) may be used instead of secondary batteries. The number of single cells **10** may be set appropriately based on the required output and the like of the cell stack **1**.

In this example embodiment, the plurality of single cells **10** are lined up in the X direction, but the invention is not limited to this. More specifically, a plurality of single cells may be used to form a single battery module, and a plurality of battery modules may be lined up in the X direction.

A positive terminal **11** and a negative terminal **12** are provided on an upper surface of each single cell **10**. The positive terminal **11** and the negative terminal **12** are electrically connected to a power generating element housed inside the single cell **10**. The power generating element is an element that charges and discharges, and may be formed of, for example, a positive plate, a negative plate, and a separator (including an electrolyte solution) arranged between the positive plate and the negative plate. The positive terminal **11** is electrically connected to the positive plate of the power generating element, and the negative terminal **12** is electrically connected to the negative plate of the power generating element.

A spacer **20** is provided between two adjacent single cells **10** in the X direction. The spacer **20** may be made of resin, for example. The spacer **20** is used to form a space on the surfaces of the single cells **10**, and this space becomes a movement passage for a heat exchange medium that is used to regulate the temperature of the single cells **10**.

When the single cells **10** are generating heat, an increase in the temperature of the single cells **10** is suppressed by flowing a heat exchange medium for cooling through the space formed between the spacer **20** and the single cells **10**. When the single cells **10** are excessively cooled, a decrease in the temperature of the single cells **10** is suppressed by flowing a heat exchange medium for heating through the space formed between the spacer **20** and the single cells **10**.

In this example embodiment, the spacer **20** is provided, but this spacer **20** may also be omitted.

A pair of end plates **31** are arranged one on each end of the cell stack **1** in the X direction. A restraining band **32** extends in the X direction, with one end of the restraining band **32** being fixed to one end plate **31** and the other end of the restraining band **32** being fixed to the other end plate **31**. By fixing the ends of the restraining band **32** to the pair of end plates **31**, restraining force is applied to the plurality of single cells **10** sandwiched between the pair of end plates **31**.

The restraining force is force that squeezes the single cells **10** together in the X direction. Applying restraining force to the single cells **10** suppresses expansion of the single cells **10** and the like, and suppresses a deterioration of the input/output characteristics of the single cells **10**.

Two of the restraining bands **32** are arranged on the upper surface of the cell stack **1**, and two of the restraining bands **32** are arranged on the lower surface of the cell stack **1**. The positions in which the restraining bands **32** are arranged may be set appropriately. For example, the restraining bands **32** may be arranged on both side surfaces of the cell stack **1** in the Y direction.

A bus bar module **40** includes a plurality of bus bars, and a holder **43** that holds the plurality of bus bars. In FIG. **1**, only the outside of the holder **43** is shown as the bus bar module **40**. The illustration of the plurality of bus bars is omitted.

The holder of the bus bar module **40** is made of insulating material such as resin. Each bus bar is connected to the positive terminal **11** of one single cell **10** and the negative terminal **12** of another single cell **10**, of two adjacent single cells **10** in the X direction. Therefore, the plurality of single cells **10** that form the cell stack **1** are electrically connected in series by the plurality of bus bars.

Next, the structure of the bus bar module **40** will be described.

FIG. **2** is a plan view of a portion of the bus bar module **40**. As shown in FIG. **2**, the bus bar module **40** includes bus bars **41** and **42**. The bus bar **41** is connected to an electrode terminal (such as the positive terminal **11**) of a single cell **10** positioned at one end of the cell stack **1** in the X direction. The bus bar **41** has an opening **41***a* through which the electrode terminal of the single cell **10** is passed. The positive terminal **11** of the single cell **10** that is connected to the bus bar **41** becomes a positive terminal of the cell stack **1**, and the bus bar **41** is connected to a high-voltage cable for charging and discharging the cell stack **1**.

Although not shown in FIG. **2**, a bus bar corresponding to the bus bar **41** is also connected to an electrode terminal (such as the negative terminal **12**) of a single cell **10** that is positioned at the other end of the cell stack **1** in the X direction. The negative terminal **12** of the single cell **10** that is connected to this bus bar becomes a negative terminal of the cell stack **1**, and the bus bar is connected to a high-voltage cable for charging and discharging the cell stack **1**. The two high-voltage cables that are connected to the positive terminal and negative terminal of the cell stack **1** are electrically connected to a load (such as the motor-generator described above).

The bus bar **42** electrically connects the positive terminal **11** of one single cell **10** to the negative terminal **12** of another single cell **10**, of two adjacent single cells **10** in the X direction. The bus bar **42** has two openings **42***a* , through which the positive terminal **11** and the negative terminal **12** are individually passed.

The holder **43** is made of insulating material such as resin, and holds the bus bars **41** and **42**. A guide portion **44** is provided on one end of the holder **43** in the X direction. This

guide portion **44** is used to bring three electric cables **50** that are fixed to the holder **43** together in one place.

The electric cables **50** may be, for example, a wire harness for transmitting output signals from a temperature sensor to a controller, a wire harness for connecting a current sensor and the cell stack **1**, and a wire harness for connecting a voltage sensor and the cell stack **1**.

The temperature sensor is used to detect the temperature of the cell stack **1**, and may be arranged in one or a plurality of locations on the cell stack **1**. A thermistor, for example, may be used as the temperature sensor. The current sensor is used to detect a current value flowing through the cell stack **1** when charging or discharging. The voltage sensor is used to detect a voltage value of the cell stack **1** or the single cells **10**. Here, when two or more single cells **10** form one block and the cell stack **1** is divided into a plurality of blocks, the voltage value of each block can be detected by the voltage sensor.

In this example embodiment, three electric cables **50** are arranged, but the invention is not limited to this. That is, the number of electric cables **50** may be set appropriately. The electric cables **50** are not limited to the wire harnesses described above, as long as they are electric cables **50** that are used to transmit specific electric signals.

FIG. **3** is a sectional view taken along line III-III in FIG. **2**. As shown in FIG. **3**, the three electric cables **50** are housed inside the guide portion **44**. The guide portion **44** includes a first guide portion **44***a* and a second guide portion **44***b* . The first guide portion **44***a* is formed of three walls, and the three electric cables **50** are arranged inside the first guide portion **44***a*.

Adhesive tape **45** is wrapped around the outer periphery of the first guide portion **44***a* , in which the three electric cables **50** are housed. The adhesive tape **45** prevents the electric cables **50** from coming out of the first guide portion **44***a* . The second guide portion **44***b* is arranged above the first guide portion **44***a*.

The guide portion **44** also includes a third guide portion **44***c* that protrudes from the first guide portion **44***a* in the X direction. The three electric cables **50** are arranged along an upper surface of the third guide portion **44***c* . A stopper **44***d* that extends in the Y direction is provided on a tip end of the third guide portion **44***c*.

As shown in FIG. **2**, a magnetic core **61** is fixed to the electric cables **50** that are drawn out of the first guide portion **44***a* . The magnetic core **61** surrounds the three electric cables **50**. The magnetic core **61** reduces noise emitted from the electric cables **50**. As shown in FIG. **4**, the magnetic core **61** is divided into two halves, i.e., a magnetic core **61**A and a magnetic core **61**B, and these two halves, the magnetic core **61**A and the magnetic core **61**B, sandwich the three electric cables **50**. A surface of the magnetic core **61** that faces the electric cables **50** is a curved surface. An outer surface of the magnetic core **61** is also a curved surface.

A first banding band **62** is arranged along the outer periphery of the magnetic core **61** and is used to fix the two magnetic core halves **61**A and **61**B together. As shown in FIG. **5**, a first fastener **63** is provided on the first banding band **62**. The first fastener **63** is able to change the positions of both ends of the first banding band **62**.

The first banding band **62** can be tightened or loosened with respect to the magnetic core **61** by operating the first fastener **63**. It is sufficient that the first fastener **63** be able to tighten and loosen the first banding band **62**. A known structure may be used as appropriate for the structure of the first fastener **63**.

As shown in FIG. **5**, a second banding band **71** is wrapped around the three electric cables **50** drawn out of the magnetic core **61**. More specifically, the second banding band **71** surrounds the three electric cables **50** and the third guide portion **44***c* . A second fastener **72** is provided on the second banding band **71**. The second fastener **72** is able to change the positions of both ends of the second banding band **71**.

The second banding band **71** can be tightened or loosened with respect to the electric cables **50** by operating the second fastener **72**. It is sufficient that the second fastener **72** be able to tighten and loosen the second banding band **71**. A known structure may be used as appropriate for the structure of the second fastener **72**.

The second banding band **71** is arranged next to the magnetic core **61** in the longitudinal direction of the electric cables **50**. When the magnetic core **61** is displaced in the direction along the electric cables **50**, the magnetic core **61** will contact the second banding band **71**. In this way, the second banding band **71** is able to prevent the magnetic core **61** from coming out of the first banding band **62**.

In this example embodiment, a connecting band **73** is connected to the first banding band **62** and the second banding band **71**, so that the first banding band **62** and the second banding band **71** can be treated as a single unit. The first banding band **62** and the second banding band **71** may also be used in a separated state.

As shown in FIG. **2**, the stopper **44***d* is formed on the tip end of the third guide portion **44***c* , so when the second banding band **71** moves in the X direction, the second banding band **71** will contact the stopper **44***d* . In this way, the stopper **44***d* is able to prevent the second banding band **71** from moving more than an allowed amount.

Next, the structure arranged inside the magnetic core **61** will be described.

FIG. **6** is a diagram of a noise reduction device **100** according to the example embodiment, and is a sectional view in the Y and Z directions of a portion including the magnetic core **61**, showing the structure arranged inside the magnetic core **61**. An adhesive tape **81** is wrapped around two electric cables **50**A and **50**B, of three electric cables **50**A to **50**C shown in FIG. **6**. FIG. **7** is a diagram showing the adhesive tape **81** wrapped around the electric cables **50**A and **50**B. By wrapping the adhesive tape **81** around the electric cables **50**A and **50**B, the electric cables **50**A and **50**B are bundled together. In this example embodiment, the adhesive tape **81** is used to make it easier to handle the electric cables **50**A and **50**B, but the adhesive tape **81** may also be omitted.

An adhesive tape **82** is wrapped around the three electric cables **50**A to **50**C and the third guide portion **44***c* . With the use of the adhesive tape **82**, it is made possible to bundle the electric cables **50**A to **50**C together, and fix the electric cables **50**A to **50**C to the third guide portion **44***c*.

In addition, with the use of the adhesive tape **82**, it is also made possible to position the three electric cables **50**A to **50**C in the longitudinal direction of the electric cables **50**A to **50**C. When a connector is provided at the tip end of each of the electric cables **50**A to **50**C, the connectors must be arranged in a predetermined connecting position. In this case, using the adhesive tape **82** to position the electric cables **50**A to **50**C makes it easier to arrange the connectors in the predetermined connecting position.

In this example embodiment, the adhesive tape **82** is used to make it easier to handle the electric cables **50**A to **50**C, but the adhesive tape **82** may also be omitted.

A long elastic sheet **83** is wrapped around the outer periphery of the adhesive tape **82**. FIG. **8** is an enlarged view of a portion of the structure inside of the magnetic core **61**. The elastic sheet **83** is a sheet that elastically deforms. EPT sealer (registered trademark) made by Nitto Denko Corporation, for example, may be used as the elastic sheet **83**. EPT sealer is a

foam and is able to elastically deform. The elastic sheet **83** is in contact with the outer peripheral surface (a portion thereof) of the adhesive tape **82**, and surrounds the three electric cables **50**A to **50**C and the third guide portion **44***c*.

In this example embodiment, the elastic sheet **83** is wrapped so as to go all the way around the outer periphery of the adhesive tape **82**. In other words, the elastic sheet **83** is wrapped so that one end portion of the elastic sheet **83** in the longitudinal direction is in contact with the other end portion of the elastic sheet **83** in the longitudinal direction. The elastic sheet **83** may be wrapped so that at least a portion of the elastic sheet **83** overlaps another portion of the elastic sheet **83**. The greater the number of times the elastic sheet **83** is wrapped around, the thicker the portion where the elastic sheet **83** overlaps becomes.

The way in which the elastic sheet **83** is wrapped may be set appropriately, taking into account the inside diameter of the magnetic core **61** and the arranging space of the electric cables **50**A to **50**C that are positioned inside the magnetic core **61** (i.e., the space that the electric cables **50**A to **50**C take up inside the magnetic core (**61**)). For example, when the arranging space of the electric cables **50**A to **50**C is equal to the space corresponding to the inside diameter of the magnetic core **61**, the elastic sheet **83** may be wrapped around only once. On the other hand, when the arranging space of the electric cables **50**A to **50**C is smaller than the space corresponding to the inside diameter of the magnetic core **61**, the elastic sheet **83** may be wrapped around a plurality of times.

In this example embodiment, the three electric cables **50**A to **50**C are used, but when only one electric cable **50** is used, for example, the way in which the elastic sheet **83** is wrapped may be set appropriately, taking into account the diameter of the electric cable **50** and the inside diameter of the magnetic core **61**. If the difference between the diameter of the electric cable **50** and the inside diameter of the magnetic core **61** is small, the elastic sheet **83** may be wrapped around only once. On the other hand, if the difference between the diameter of the electric cable **50** and the inside diameter of the magnetic core **61** is large, the elastic sheet **83** may be wrapped around a plurality of times.

The elastic sheet **83** elastically deforms when it is assembled inside the magnetic core **61**. In other words, the elastic sheet **83** is wrapped such that the wrapped elastic sheet **83** is pressed by the magnetic core **61** so that it elastically deforms.

When the elastic sheet **83** is elastically deformed, the restoring force of the elastic sheet **83** is applied to the magnetic core **61** and the electric cables **50**A to **50**C. As a result, it is possible to attach the magnetic core **61** to the electric cables **50**A to **50**C so that it will not slip. More specifically, using the elastic sheet **83** makes it possible to inhibit the magnetic core **61** from sliding in the longitudinal direction of the electric cables **50**A to **50**C, and inhibit the magnetic core **61** from rotating around the electric cables **50**A to **50**C.

Inhibiting the magnetic core **61** from sliding with respect to the electric cables **50**A to **50**C makes it possible to prevent the noise reduction effect of the magnetic core **61** from changing. That is, the noise reduction effect of the magnetic core **61** is made stable.

According to the example embodiment, even if the arranging space of the electric cables changes with respect to the space formed inside the magnetic core **61**, all that need be done is to simply change the way in which the elastic sheet **83** is wrapped. That is, when the magnetic core **61** having a certain inside diameter is attached on different electric cables **50** having different diameters, the magnetic core **61** can be fixed to the electric cable **50** simply by changing the way in which the elastic sheet **83** is wrapped. In this example embodiment, all that need be done is to change the way that the elastic sheet **83** is wrapped, and therefore, there is no need to change the elastic sheet **83** depending on electric cables **50** with different diameters.

Further, the elastic sheet **83** is arranged between the magnetic core **61** and the electric cables **50**A to **50**C, so that the magnetic core **61** is prevented from contacting the electric cables **50**A to **50**C. As a result, the magnetic core **61** is prevented from damaging the outer surfaces of the electric cables **50**A to **50**C.

A highly wear-resistant sheet **84** is wrapped around the outer peripheral surface of the elastic sheet **83**. Here, the sheet **84** is wrapped so as to allow the elastic sheet **83** to elastically deform. More specifically, the sheet **84** is wrapped such that the elastic sheet **83** is in its natural state. If the elastic sheet **83** is constricted when the sheet **84** is wrapped around it, it would be more difficult to apply the restoring force of the elastic sheet **83** to the magnetic core **61** and the electric cables **50**A to **50**C, and it would therefore become more difficult to fix the magnetic core **61** to the electric cables **50**A to **50**C.

The sheet **84** is positioned between the elastic sheet **83** and the magnetic core **61**, so that the sheet **84** is in contact with the outer peripheral surface of the elastic sheet **83** and the inner peripheral surface of the magnetic core **61**. Tesa tape made by tesa tape, inc., for example, may be used as the sheet **84**.

Arranging the wear-resistant sheet **84** on the inner peripheral surface of the magnetic core **61** prevents the magnetic core **61** from contacting the outer peripheral surfaces of the electric cables **50**A to **50**C and the elastic sheet **83**, and thus prevents the electric cables **50**A to **50**C and the elastic sheet **83** from becoming damaged.

The invention has been described with reference to example embodiments for illustrative purposes only. It should be understood that the description is not intended to be exhaustive or to limit form of the invention and that the invention may be adapted for use in other systems and applications. The scope of the invention embraces various modifications and equivalent arrangements that may be conceived by one skilled in the art.

The invention claimed is:

1. A noise reduction device for use with a bus bar module having a holder, the noise reduction device comprising:

a magnetic core configured to surround an outer periphery of an electric cable;

an elastic sheet configured to wrap around the electric cable so as to surround the electric cable, the elastic sheet being disposed between an inner peripheral surface of the magnetic core and an outer peripheral surface of the electric cable and elastically deformed, and at least a first portion of the elastic sheet overlaps a second portion of the elastic sheet; and

a guide portion of the holder disposed between the elastic sheet and the electric cable.

2. The noise reduction device according to claim **1**, further comprising:

a wear-resistant sheet that is arranged between the magnetic core and the elastic sheet.

3. The noise reduction device according to claim **1**, wherein the magnetic core and the elastic sheet surround a plurality of the electric cables.

4. The noise reduction device according to claim **3**, further comprising: an adhesive tape that bands the plurality of electric cables together.

5. The noise reduction device according to claim **1**, wherein the elastic sheet is formed of a foam material.

6. A bus bar module comprising:

a plurality of bus bars for electrically connecting a plurality of power storage elements together;

a holder that holds the plurality of bus bars and is made of insulating material;

an electric cable, one end of which is fixed to the holder and a portion on the other end side of which is drawn out of the holder; and

the noise reduction device according to claim 1.

7. The bus bar module according to claim 6, further comprising

a plurality of the electric cables, wherein

the guide portion is configured to guide the plurality of electric cables to an attaching position of the noise reduction device.

8. A manufacturing method for a noise reduction device for use with a bus bar module having a holder, the noise reduction device including a magnetic core configured to surround an electric cable, the method comprising:

providing the electric cable and a holder having a guide portion;

wrapping an elastically deformable elastic sheet around the electric cable and the guide portion so that the elastic sheet surrounds the electric cable and the guide portion, the elastic sheet having a first portion and a second portion where the first portion overlaps the second portion; and

elastically deforming the elastic sheet by attaching the magnetic core to the electric cable that is surrounded by the elastic sheet.

9. The manufacturing method for a noise reduction device according to claim 8, wherein

in wrapping the elastic sheet around the electric cable, a wrapped state of the elastic sheet with respect to the electric cable is changed according to a diameter of the electric cable and an inside diameter of the magnetic core.

10. The noise reduction device according to claim 1, wherein a number of times the elastic sheet is wrapped around the electric cable is changed according to a diameter of the electric cable and an inside diameter of the magnetic core.

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